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JOINT SEALANTS FOR AIRPORT PAVEMENTS

Phase I: Laboratory and Field Investigations

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16. Abstract

The objectives of this study were to determine the essential characteristics of sealants for joints in Portland cement concrete (PCC) airport pavements that should be incorporated in specifications and select best candidate sealants for field evaluation. Laboratory and field investigations of sealants were performed for data needed to meet these objectives. Major factors that sealants must be resistant to are: chemicals (jet fuel, hydraulic fluid, lubricating oil), physical (elongation, compression, intrusion), and environmental (thermal, sunlight, weathering). In laboratory specification conformance tests, only 3 of 18 (17%) of the sealants passed the tests. In field inspection of sealants and discussions with airport personnel, there was no one clearly outstanding performing seal that was identified; however, several airports favored the Dow Corning 888 silicone seal. There is a strong indication of material of specification (or both) deficiencies. Sealants selected for evaluation in Phase II have the following material compositions: silicone, polyurethane, coal tar/polyvinyl chloride, and chloroprene.

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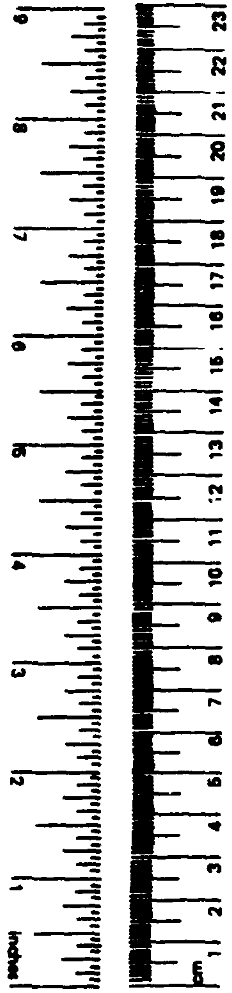
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

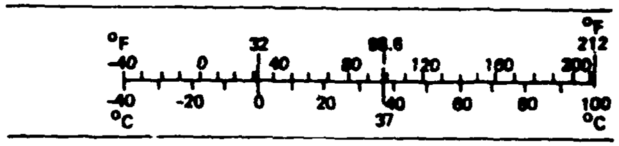
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.4[illegible]	liters	l
qt	quarts	0.[illegible]	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

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Denver Stapleton International - Mr. Jack Brennan, Mr. Charles L. McClure.

Dulles International - Mr. David A. Jones, Mr. Rick McLaughlin, Mr. H.D. Campbell, Jr. of Campbell, McQueen, and Paris Engineers, Herndon, Virginia.

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EXECUTIVE SUMMARY

The objectives of this study were to determine the essential characteristics of sealants for joints in portland cement concrete (PCC) airport pavements that should be incorporated in specifications, and select best candidate sealants for field evaluation. Laboratory and field investigations of sealants were performed for data needed to meet these objectives. Major factors that sealants must be resistant to are: chemical (jet fuel, hydraulic fluid, lubricating oil); physical (elongation, compression, intrusion); and environmental (thermal, sunlight, weathering). In laboratory specification conformance tests, only 3 of 18 (17 percent) of the sealants passed the tests. In field inspection of sealants and discussions with airport personnel, no one clearly outstanding performing seal was identified; however, several airports favored the Dow Corning 888 silicone seal. There is a strong indication of material or specification (or both) deficiencies. Sealants selected for evaluation in Phase II have the following material compositions: silicone, polyurethane, coal tar/polyvinyl chloride, and chloroprene.

INTRODUCTION

Objectives

The objectives of Phase I efforts were to: (1) determine essential characteristics of joint seals for portland cement concrete (PCC) airport pavements, (2) develop preliminary recommendations of such characteristics for incorporation in specifications, and (3) select best candidate seals for field testing in Phase II.

Scope of Investigation

A comprehensive approach was taken to accomplish the goals of this investigation. The following activities were performed to meet the objectives of this study:

1. Searches for literature and ongoing and previous joint seal research - in electronic data bases.

2. Product searches - in electronic data bases.

3. Contacts with FAA regional engineers.

4. Field inspection at six airports.

5. Qualitative assessment of joint seals with aircraft chemicals.

6. Specification conformance and other laboratory tests of joint seal samples.

7. Analysis of data and formulation of findings and recommendations.

Background

The life and performance of PCC pavement joint seals are not good. This has been the experience at both civilian airports and military airfields. The performance has been similar because the same specifications are being used for both civilian and military facilities. For example, in Item P-605, Joint Sealing Filler, of the Federal Aviation Administration (FAA) Advisory Circular (Reference 1), the use of Federal Specification SS-S-200 - Sealing Compounds, two-component, elastomeric, polymer type, jet-fuel resistant cold applied is prescribed. This same federal specification must be used for joint seals at military airfields. In a systematic random survey of 19 Navy and Marine Corps Air Stations, it was found that 63 percent experienced joint seal failures within the first 4 years after joint seal application. The amount of seal failure

at these stations ranged up to 60 percent. The poor performance of joint seals at civilian airports has been similar to the Navy's experience, as will be discussed later in this report.

Initial research efforts included searches in electronic data bases to identify ongoing and previous investigations in pavement joint seals. Searches for research projects, reports, and articles were made in the following data bases: Defense Technical Information (DTIC), National Technical Information Service (NTIS), Compendex Plus (Engineering Index), Transportation Research Information Services (TRIS), and Federal Research in Progress. There were no ongoing or previous research efforts identified that this research effort would duplicate; hence, the planned research efforts were pursued. There is a considerable amount of published information pertaining to joint seals, especially as they relate to highway pavements. Some of the information pertains to evaluating joint seals in actual service on selected highways (References 2, 3, 4, 5, and 6). Because of differences in slab sizes, traffic conditions, environmental conditions, and the presence of spilled chemicals (fuels, oils, etc.) on airport pavements, research results from highway pavements are not directly applicable. The basic parameters (i.e., sealant properties, joint design, and installation workmanship) however, are the same for airport pavements. Because of continuing research in joint seals for highway pavements, this is an indication that sealant problems for such pavements remain unresolved.

The Navy and Army have performed research on airfield pavement joint seals The Navy's effort is concentrated primarily on jet blast (temperature and velocity) and chemically resistant seals. Jet blast from military aircraft has a much more significant effect on joint seals than commercial aircraft because the engines are closer to the pavement and the exhaust plume is directed onto the pavement. Chemical spillage is also a more significant factor because military aircraft inherently spill fuel upon shutdown. Thus, the focus of Navy research is different from the study reported herein which has its focus on optimizing present joint seals. The Army's research effort, which was funded by the Air Force, is on evaluating several types of joint seals at selected Air Force bases. Findings thus far indicate that there is no one sealant that is superior to the others and therefore, the joint sealant problem for military airfield pavements remains unresolved.

Definitions

A glossary of joint seal terms and related procedures is included in Appendix A. The glossary was prepared to facilitate defining and clarifying terminology used in this report which is peculiar to the joint sealing technology. These terms were derived from References 7 and 8.

ACCOMPLISHMENTS

Preliminary Survey for Failure Mechanisms

To determine how joint sealants were failing and which sealants performed the best, all FAA Regional Offices and six airports were surveyed. The survey of FAA Regional Offices was conducted in November

1986. The seven regional offices contacted were: Alaska, Northwest-Mountain, Western-Pacific, New England, Southwest, Eastern, and Southern. Each of the region's pavement engineers were asked to identify the best performing joint seal and typical defects observed in his-her region. Each regional pavement engineer was also asked about contacts at airports for the site survey.

The results of the survey of FAA regional engineering offices were inconclusive. The pavement engineers at the regional offices had no data on what were the best performing seals or typical defects in their respective regions. In some of the regions, the use of portland cement concrete (PCC) pavement is avoided because of climatic conditions; in colder climates, ice-heaving of PCC pavements is a problem. For this reason, asphalt concrete (AC) is used. All regional offices recommended contacting the individual airports for more data. However, a few of the regional offices were aware of good performance by silicone sealants in highway applications. These regional offices believe that silicone sealants may also perform well in airport applications. These offices were aware of applications on smaller airports, but not on major airports. The silicone products these offices were aware of were Dow Corning 888 and one from General Electric. Table 1 summarizes the findings of the survey of FAA regional engineers.

Selection of Airports for Survey

The six airports surveyed were selected based on the following criteria: (1) PCC pavement must be present, (2) must be in different climatic zone as defined in Reference 9, and (3) must be a major hub airport. The requirement for PCC pavement was obvious. In addition, a variety of PCC pavement types (e.g., runway, taxiway, apron) was desired so assessments could be made with respect to service conditions. Climatic variation was used as a selection criteria to determine if any correlations existed between joint sealant performance and the environment in which they were installed. Figure 1 illustrates the various climatic regions, based on freeze-thaw and moisture, from which the six airports were selected. A major hub airport was desired as a criteria because traffic exposure would tend to be a representative sampling of U.S. aircraft. The six airports selected according to the foregoing criteria were: Chicago O'Hare, Dulles, Atlanta Hartsfield, Denver Stapleton, Dallas/Fort Worth, and Los Angeles. The selected airports and their corresponding climatic zones (Reference 9) are listed in Table 2.

The airport site investigations were conducted in January and February 198[illegible]. The airports were individually visited and a standard list of questions (Appendix B) was used for the site investigation. The airport engineers or maintenance supervisors were asked questions on sealants used or preferred, life of sealant, sealant defects, location, etc. These airport officials also assisted in the inspection of their joint seals.

Qualitative Assessment of Sealant-Aircraft Fluid Compatibility

A qualitative non-laboratory study on the compatibility of sealant materials with aviation fluids was conducted at NCEL. This study was based on information from manufacturer's literature, Material Safety

Data Sheets (MSDS), and information on aviation fluids. Durability ratings were made for each sealant versus a particular fluid that was based on judgment of their long term (2 to 5 years) compatibility. A matrix was developed on the durability ratings.

Laboratory Tests

The selection of candidate seals for the laboratory tests was based on findings from the airport site investigations and the product searches. Sealants installed at the airports and identified in the surveys were automatically considered as candidates for testing. Additionally, other candidates were identified through the product searches in electronic data bases and through an advertisement in the Commerce Business Daily for sealant manufacturers. Twenty joint sealants, as shown in Table 3, were selected for laboratory testing. Sources for the sealants are shown in Appendix C.

Infrared (IR) spectroscopy was conducted to characterize the chemical composition of each of the candidate sealants. The infrared instrument used was a Biorad FTS-60. Infrared (IR) spectra were taken on both the cured and uncured sealants to determine the major chemical components. For transparent samples, the sealant was placed between two sodium chloride plates. For opaque samples, the sealant was pressed between KRS-5 (thallium bromoiodide) plates and a surface reflection technique known as attenuated total reflectance (ATR) was used to obtain IR spectra. From the spectra data, a chemical characterization was developed. The sealant material's chemical characterization was then correlated with failure mechanisms observed in the field and in the laboratory. By identifying particular chemical characteristics with performance, recommendations can be made as to which chemical characteristics affect good sealant performance.

Specification conformance tests of candidate seals were conducted because we observed failures in the field despite conformance and manufacturers' claims. For example, jet-fuel resistant sealants were observed to be failing prematurely because of exposure to jet fuel and hydraulic fluid. Sealants failing in the field, despite passing the conformance tests, may indicate that the specifications or material (or both) are inadequate. The specification tests used to test the sealants are those identified in FAA Advisor Circular, Item P-605, Joint Sealing Filler (Reference 1). Item P-605 allows conformance to Federal and ASTM Specifications, such as Federal Specification SS-S-200 and ASTM D 3569, D 3405, D 2628, etc.

Additional chemical resistance tests were conducted to simulate conditions found in the field which are not included in current specification conformance tests. Current specifications do not test for hydraulic fluid or lubricating oil immersion, yet findings from the airport site survey indicate that these aviation fluids do deteriorate joint seals. Therefore, chemical resistance tests, based on current joint seal specifications, were conducted by immersing the samples in hydraulic fluid and lubricating oil. A control group was also tested using Reference Fuel B (ASTM D-491) as specified in Federal Specification SS-S-200E and ASTM D 3569-85.

DISCUSSION

Airport Survey Results

Findings from the site surveys, such as sealant failures, type and manufacturer of sealant, age, and specification are summarized in Table 4 and discussed below.

Chicago O'Hare International Airport officials prefer using Crafco Roadsaver RS-201 (ASTM D 3405), a hot-poured asphalt-rubber sealant. They highly recommend this sealant for its elasticity and pliability. They have not experienced oil and fuel damage of this rubberized asphalt sealant even though it's not specified as jet-fuel resistant. They have used this sealant for the past 6 years with no major problems. When they develop specifications for joint resealing, they specify the Crafco RS-201. The field inspection has found the Crafco RS 201 to be generally in good condition. Typical defects were hardness and extrusion of the sealant. A lot of the hardness may be due to the cold temperatures during the inspection. They currently use the Crafco for all of their joint resealing programs. They have also used W.R Meadows Sealtight Poly-Jet JFR (ASTM D 3581) and W.R. Meadows Sealtight Hi-Spec (ASTM D 3405) on new construction with limited success. There were no examples of joints with the W.R. Meadows sealants available for examination.

At Dulles International Airport, the airport engineer had no data on what their best performing sealants were or their typical defects. The Dulles engineers had records of sealant specifications used for a recent project, but not what product was actually installed. They did, however, provide data on a sealant product used for a joint resealing project. The sealant was NEA 1614, conforming to Federal Specification SS-S-1614. The airport engineer recommended contacting a local contractor experienced with the design and construction of airport pavements and joint sealants.

The contractor's sealant preferences were: Dow Corning 888 (silicone) and W.R. Meadows Poly-jet JFR (ASTM D 3581), in order of preference. The contractor highly recommended Dow Corning 888 over the others, despite its higher initial cost. The only defect he was aware of with the Dow Corning silicone was swelling during exposure to jet fuel. He claimed that the swelling reduced and returned to its original size after exposure to the jet fuel; however, he believed this was not a serious problem. The contractor knows three airports that use the Dow Corning 888: Roanoke, Virginia, Norfolk International, and Baltimore-Washington. The contractor provided the following information for these airports: at Roanoke Airport, Virginia, they have had the 888 in service for 8 years; at Norfolk International, Virginia, the 888 has been in service in aprons, taxiways, and runways for about 5 years; and at Baltimore-Washington Airport, the 888 was installed in 1984 on a parking apron. He recommended the W.R. Meadows Poly-Jet JFR because the manufacturer certifies specification conformance. He also recommended using preformed compression seals only on new construction because the geometry of the joint walls must be very precise. Poor workmanship also should not be tolerated with preformed seals. The contractor disliked two-component cold-applied sealants because mixing the two components must be exact and incorrect mixing frequently occurs during installation.

At Atlanta International Airport, the airport officials preferred seals that conform to Federal Specifications SS-S-1614 or ASTM D 3581. They prefer this specification over Federal Specification SS-S-200D. They have a lot of sealant failures with a 200D material made by Allied. The Allied 200D material had adhesion failures, surface bubbles, and crystallization on the surface. They have had some success with Federal Specification SS-S-1614 seals, Superseal 777, and Allied 9012. They have also had some success with preformed neoprene seals in transverse, sawed joints. The preformed seal tney have tried is manufactured by Watson, Bowman, and Acme. They are also trying Dow Corning 888 silicone and Ruscoe 983 nitrile rubber sealants. The Superseal 777 was found to be brittle and hard. In some cases it was hard completely through the depth of the joint. This resulted in complete adhesion failure. There were also signs of cohesion failure. The 200D material was found to have adhesion failure, surface bubbles, blistering, and crystallization on the surface. The preformed compression seals were found to have oxidation, compression set, and adhesion loss.

Denver International Airport officials had a definite preference for Dow Corning 888 silicone sealant. They installed it on some of their parking aprons 2 to 3 years ago. They have had no major problems with the sealant, despite being located in an area of severe service conditions (i.e., parking apron). However, silicone swells when exposed to jet fuel, but bonding to the joint walls remains satisfactory. Swelling eventually dissipates and the sealant returns to its original shape. The general performance of the sealant seems to be unaffected by swelling. Examination of the 888 found the silicone to be in very good condition. The sealant was pliable, despite the cold weather during the examination. There was no evidence of deterioration from jet fuel or hydraulic oil spillage or even swelling as described. Their second preference was the Crafco Roadsaver RS-201 (ASTM D 3405) hot-poured rubberized asphalt sealant. They have had moderate success with this sealant. A common defect found on the Crafco was its hardness. They also like preformed neoprene sealants (ASTM D 2628), but only in new construction in transverse joints. They did not recommend this type of sealant on resealing. They tried Superseal 777 (ASTM D 3569) in the past and observed very poor performance. Examination of the 777 found hardness, cracking, shrinkage, and complete adhesion loss. In some areas the sealant was completely failed (i.e., it was absent (pulled out) from the joint).

Dallas/Fort Worth International Airport recently installed Dow Corning 888 silicone on a newly constructed runway. Airport officials believe that this type of sealant will perform very well, based on Denver International Airport's experience with this sealant. In the past Dallas/Fort Wirth has used both a hot-poured sealant and preformed seals. They prefer the hot-poured over the preformed seal. The preformed seal developed compression set and lost its adhesion. Eventually, the seal was pulled out by aircraft traffic. There were no records of the manufacturers of the hot-poured and preformed seals. The Dow Corning 888 was installed on runways and taxiways at Dallas/Fort Worth. The preformed seal was also installed on runways and taxiways.

Los Angeles International Airport officials have a definite preference for the Grove GS-1450 two-component cold-applied polyurethane sealant (Federal Specification SS-S-200). They have also tried Pacific

Polymers Elasto-Thane 5639 (Federal Specification SS-S-200) and Superseal 777 (ASTM D 3569). They found that the Grove performed the best of the three. The Grove seal inspected has been in place for 7 years and was in reasonable condition. The defects found were adhesion loss, blistering, and Skydrol hydraulic oil damage. The Pacific Polymers sealant inspected was installed 5 to 6 years ago. The defects found were adhesion loss, hardness, and complete seal loss. The Superseal 777 has been in place only 2 to 3 years and already had numerous defects, such as adhesion loss, hardness, jet-fuel damage, Skydrol hydraulic oil damage, and bleeding. All of these sealants were installed in areas of severe service conditions, such as parking aprons and maintenance areas, where the sealants were exposed to aviation fluids and debris.

Preferred Joint Sealants

Field observations show that the Dow Corning 888 silicone sealant is the most preferred sealant. Other highly preferred sealants were the Crafco RS-201 (ASTM D 3405) and the Grove GS-1450 (Federal Specification SS-S-200E). These three sealants were definitely preferred by particular airports. The Dow Corning 888 was preferred at Denver and is being tried at Dallas/Fort Worth and Atlanta. The 888 is also preferred by a contractor specializing in airport pavement construction. The Crafco RS-201 is preferred at Chicago and is Denver's second choice after the 888. The Grove GS-1450 is preferred at Los Angeles. The other airports did not have a definite preference. For example, Atlanta prefers a specification type (Federal Specification SS-S-1614) and not a specific product. There is no single preferred specification, as shown by the three preferred sealants and their specifications. All three sealants have different specifications, i.e., liquid hot-poured (ASTM D 3405) one-component, silicone, and two-component liquid (Federal Specification SS-S-200). The sealant preferences of each of the airports are summarized in Table 5.

Joint Seal Failure Mechanisms

The sealant defects observed at the six airports could be caused by inadequate materials, improper installation, or improper design. However, in many cases these defects could not be absolutely linked to one source. The mechanisms of failure may be due to a combination of causes. For example, the loss of bond between the seal and joint wall (adhesion loss) may be caused by one or any combination of the following: (1) low adhesive strength (inadequate material), (2) insufficient cleaning of joint before placing sealant (improper installation), or (3) using the incorrect shape factor (improper design).

Damages from jet fuel and hydraulic fluid were found on parking aprons and maintenance areas where aircraft are fueled and serviced (Figure 2). Even though a particular sealant was specified as "jet-fuel resistant," the sealant was found damaged by these fluids. For example, at Los Angeles International Airport, after only 2 years, a "jet-fuel resistant" seal showed signs of deterioration by jet fuel (Figure 3). Hydraulic fluid appears to affect sealants just as much as jet fuel. Figure 4 shows an example of a jet-fuel resistant seal that has been

almost completely deteriorated by hydraulic fluid. Current specifications for joint sealants require jet-fuel resistance, but not hydraulic fluid resistance.

Adhesion loss occurs when the bonding between the sealant material and the walls of the joint fails. An example of adhesion failure is shown in Figure 5. Adhesion loss can be caused by improper cleaning during installation, inadequate materials, and improper shape factor (References 7, 10). Adhesion loss was found in varying degrees of severity at all of the airports and in every area of the airports (i.e., parking apron, taxiway, etc).

Cohesion loss occurs when the sealant material fails from tensile forces while maintaining a bond between the sealant and joint wall (Figure 6). This type of defect can be caused by inadequate material and an improper shape factor (depth/width ratio) for the material (References 7, 10). Cohesion failure was found in every area of the airports surveyed. Research has found that elastomeric low modulus silicone and elastomeric sealants need different shape factors to lower the stresses in the sealant. The shape factor for the sealant material, if too large, can induce increased stresses in the sealant and lead to cohesion failure. The material capabilities may also be inadequate for the required joint movement, regardless of the shape factor, if the maximum allowable strain for the material is exceeded.

Sealant hardness occurs when the sealant loses pliability and resiliency. The seal is unable to contract and extend with the movement of the pavement. The sealant eventually fails in cohesion or adhesion because of the increased stresses in the sealant. Figure 7 shows an example at Denver International Airport where the sealant became hard, lost adhesion, and eventually pulled out of the joint completely from wheel traffic. Hardness was found at all airports surveyed and in all area of these airports (i.e., runways, parking aprons, etc). Hardness may be caused by weathering, aging, or low temperatures. This indicates that the material may be inadequate for the these environmental conditions.

Failure due to intrusion of incompressibles occurs when the sealant is soft enough to allow small rocks to embed in the sealant. The intrusion of incompressibles prevents the compression of the sealant and expansion of the pavement. When the pavement cannot expand, compressive stresses in the pavement cause blow-ups. However, we also observed "harder" sealants that resisted entry of incompressibles, but induced higher stresses within the sealant creating cohesive or adhesive failures. There should be a balance between resiliency and resisting the intrusion of incompressibles. Allowing intrusion of incompressibles indicates an inadequate material.

Sealant material properties, such as resiliency and tensile strength, are also affected by temperature variations. In colder temperatures some sealants become hard and less resilient. In addition, the pavement is also at its maximum contraction (i.e., at maximum joint width) during colder winter months. Conversely, during summer months the sealant can become soft and fluid during maximum pavement expansion (i.e., minimum joint width), which may extrud the sealant from the joint. This combination of material deficiency and seasonal pavement movement creates greatly increased tensile stresses in the sealant which may lead to cohesive or adhesive loss.

Compression set in a preformed compression seal occurs when it loses its resiliency and permanently retains its deformed shape. Figure 8 shows an example of a preformed seal with compression set. Such a seal can no longer expand as a joint increases in width and the seal against the joint walls is lost. This allows water and incompressibles to enter the joint which can result in damage to the pavement system. This defect is probably caused by poor seal material or poor adhesive/lubricant. (An adhesive/lubricant is used to aid installation of the seal and adhesion.)

The shape factor (depth-to-width ratio) greatly influences a joint seal's effectiveness. A method was developed by E. Tons (Reference 11) to determine the strain along the parabolic curve of the sealant during extension. The strain was determined for the width and depth of the sealant, the amount of joint movement, and minimum joint crack opening. For example, if the shape factor is large (i.e., narrow and deep), internal stresses increase and can lead to cohesive failures. A backer rod should be used to maintain the correct shape. The correct shape means parabolic curves along the top and bottom of the seal and adhesion along the sides of the joint wall. If a backer rod is not used, undesirable adhesion along the joint bottom is created. The correct shape factor is also influenced by the type of sealant material (References 7, 11, 12). Elastomeric low modulus silicone and elastomeric hot-poured sealants require different shape factors to lower stresses and strains in the sealant. A shape factor of 1/2 is recommended for silicone and closer to 1 is recommended for hot-pour sealants. This is all based on the maximum allowable strain of the material (Reference 12).

An important factor in installing seals successfully is a clean joint. All dirt, old sealant residue, or any loose material must be removed before installing a joint seal. The recommended method of joint cleaning is sandblasting (Reference 10).

The Navy has a problem of jet-heat and blast damage to joint seals. There were no jet-heat or blast related damages observed at the six commercial airports surveyed. Airport personnel also indicated that they have had no problems with jet-blast related damage in the past. Commercial airports may not have this problem because commercial aircraft engines are generally located higher above the pavement and their blast is not directed downward as in military aircraft.

In summary, factors that affect seal performance fall into two groups: (1) material, and (2) physical. Material factors are: resistance to aviation fluids (jet fuel, hydraulic fluid, turbine oil, etc.), adhesive strength, cohesive strength, resistance of the intrusion of incompressibles, resistance to weathering and aging, and resiliency and pliability. Physical factors are: joint design (e.g., shape factor, joint movements, climate, etc.) and installation quality (e.g., cleaning of joint, proper mixing or heating, etc.). However, in general the joint sealant defects observed could not be linked directly to any one particular failure mechanism. Most of the failures may be caused by a combination of mechanisms.

Based on the above findings, installed airport pavement joint seals should be considered as systems where different combinations of interrelated parts impact seal performance and failure. This system includes the pavement and joint spacing which dictates joint movements, the type

of sealant material, and shape factor. This sealing system should prevent the intrusion of excessive moisture and debris into the joint, but allow cyclic pavement movements and maintain bond and cohesion while exposed to an airport's environmental conditions. Environmental conditions which affect this system are: all aviation fluids (jet fuel, hydraulic oil, etc.), weathering and aging, and intrusion of incompressibles. Therefore, joint seal specifications should emphasize the above performance criteria and environmental conditions on the entire sealing system regardless of sealant type.

Infrared Spectroscopy Results

In the infrared (IR) spectroscopy analyses of the sealants, the following major material components were identified: asphalt, chloroprene, coal tar, polyvinyl chloride, polyurethane, rubber, and silicone. The results of the IR analyses identifying major material components of the joint sealants are summarized in Table 6. Most of the liquid sealants (except for the silicones and two polyurethanes) contain high molecular weight hydrocarbons such as coal tar or asphalt in their compositions. Polyvinyl chloride (PVC) and polyurethanes were mixed with coal tar and rubber with asphalt to strengthen or change properties of the sealant; and possibly to increase jet-fuel resistance. Both natural (polyisoprene) and synthetic (chloroprene or neoprene) rubbers were found in the sealants. Natural rubbers were found as mixtures with asphalt liquid sealants and the synthetic rubbers in the preformed compression seals. Polyurethanes were used to strengthen coal tar sealants, except for two which were mostly polyurethane with no coal tar. Silicone was in a liquid form.

The Federal Specification SS-S-200E sealant materials tested are made up of coal tar, coal tar/polyurethane, and polyurethane compositions. The ASTM D 3569 or Federal Specification SS-S-1614 materials tested are made up of coal tar, coal tar/polyvinyl chloride compositions. The ASTM D 3405 or Federal Specification SS-S-1401 materials are made up of asphalt or asphalt/rubber compositions. The ASTM D 2628 (preformed compression seals) are chloroprene (neoprene) materials. The remaining seals are composed of silicone and nitrile rubber and currently have no specification for airport pavement use.

Specification Conformance Test Results

The results of our specification conformance tests of the 20 sealants are summarized in Table 7. Most of the 20 sealants failed their respective specification conformance test. This indicates that many of the field observed failures are due to inadequate materials. Only three of 18 of the sealants (17 percent) tested passed. The raw test results of the specification conformance and additional tests are summarized in Tables 8A, 8B, 9A, 9B, 10, and 11.

Results of immersion tests in aviation fluids (jet fuel, hydraulic fluid, and lubricating oil) are tabulated in Table 12. These data were derived from specification conformance tests and the additional test results. Comparing sealant material composition and immersion test results in Table 12, the following can be concluded:

1. Jet-Fuel Resistance. The fuel (Reference Fuel B, ASTM D 471) immersion data show that coal tar, coal tar/polyvinyl chloride have the least percent change in weight. The addition of polyurethane with the coal tar shows increased percent change in weight by fuel immersion. Sealant material with mostly polyurethane and no coal tar have a much higher percent change in weight. This indicates that coal tar has good resistance to jet fuel and that the addition of polyurethane decreases the resistance to jet fuel. The addition of polyvinyl chloride does not seem to affect jet-fuel resistance of coal tar. The silicone (Dow Corning 888) appears to increase in weight after immersion of jet fuel, as shown by a negative value in Table 12. This percent change in weight is also relatively high as compared with the other sealants. This confirms field survey findings that this seal swells during jet-fuel exposure.

2. Hydraulic Fluid Resistance. From the additional tests, the hydraulic fluid (MIL SPEC H-83282B) immersion data show that coal tar/polyvinyl chloride compositions are the most resistant to this fluid. The silicone composition (Dow Corning 888) increases in weight under immersion of hydraulic fluid. It appears that hydraulic fluid, as well as jet fuel, swells the silicone.

3. Lubricating Oil Resistance. The effects of lubricating oil (MIL SPEC L-23699C) immersion shows a less definitive correlation with material change in weight. However, the silicone (Dow Corning 888) has the least change in weight and the polyurethanes have the most. The coal tars rank between silicones and polyurethanes.

In summary, the coal tars or coal tar/polyvinyl chloride are the most resistant to change in weight due to immersion of jet fuel, hydraulic fluid, and lubricating oil. Coal tar or coal tar/polyvinyl chloride is considered to be highly resistant to jet fuel (Reference 7). The majority of sealants that contain these materials (coal tar, coal tar/polyvinyl chloride) conform to Federal Specification SS-S-200E, ASTM D 3569, or Federal Specification SS-S-1614, all of which specify jet-fuel resistance. The asphalt or asphalt/rubber sealants conform to ASTM D 3405 or Federal Specification SS-S-1401, which do not specify jet-fuel resistance.

Qualitative Assessment of Sealant-Aircraft Fluid Compatibility Results

The qualitative non-laboratory study on the compatibility of seal material with aviation fluids concluded that most of the aviation fluids will attack and dissolve coal tar, asphalt, and polyvinyl chloride (PVC) formulations. Many of the solvents will soften or dissolve asphalt in asphalt-polyurethane combinations. Polyurethanes are moderately resistant, while the silicones are the most resistant. The natural rubber will swell in the presence of many hydrocarbons. The synthetic rubbers (chloroprene) are more chemically resistant, but may swell or dissolve in hydraulic fluid. This shows that certain formulations are inherently incompatible with aviation fluids and should be avoided, or at least in areas of high exposure to these fluids such as parking aprons and maintenance areas. General material types and their compatibility to typical aviation fluids are summarized in Table 13. A qualitative estimation of the chemical resistance of specific joint sealants to typical aviation fluids is summarized in Table 14.

SELECTION OF BEST SEALS FOR PHASE II FIELD TESTS

The criteria and procedure used in determining the best candidate seals, based on laboratory test results, for field testing in Phase II are as follows:

1. Only seals for which there are complete test data as documented in Tables 8a through 11 were considered as candidates.

2. Nonjet-fuel resistant seals were excluded because of the necessity of this requirement.

3. Only quantitative test results were considered; qualitative and judgmental data were not considered.

4. The score assigned to each seal was simply its relative ranking (i.e., "1" is best, "2" next best, etc.) among all of the seals in meeting the conformance requirements of each particular test.

5. The total score for each seal is the sum of the individual scores for each test.

6. The seal with the lowest total score is selected as the best candidate.

The results of following the above procedure are summarized in Tables 15a, 15b, and 15c.

The selection of the best seals was based on the assessment of the results shown in Tables 15a, 15b, and 15c and findings from the airport surveys. Information on the selected seals for field testing in Phase II is presented in Table 16. Note that Dow Corning 888 sealant is included in the list. The selection of the silicone seal was determined from findings from the airport site surveys. Currently, silicone seals are not included in the FAA Advisory Circular, Item P-605, Joint Sealing Filler, but Dow Corning 888 silicone was the most preferred seal based on the airport site survey findings.

CONCLUSIONS

1. The pavement engineers at FAA Regional Offices who were surveyed for the best performing seals and typical seal defects occurring within their regions, showed that such data were not generally available through their offices. However, engineers at both Southwest and Eastern Regions had favorable comments on silicone sealants.

2. Various laboratory tests were conducted on 20 joint sealants for which the following results were obtained:

a. Specification Conformance Tests. Only three of 18 (17 percent) seals passed the standard Federal Specification or ASTM designated tests for the respective sealant.

b. Infrared Spectroscopy Analyses. Determined material composition of various Federal and ASTM specification sealants analyzed:

Federal or ASTM Specification	Material Composition
SS-S-200	Coal Tar Polyurethane Coal Tar/polyurethane
SS-S-1614 (ASTM D 3569)	Coal Tar Coal Tar/polyvinyl chloride
SS-S-1401 (ASTM D 3405)	Asphalt Asphalt/rubber
ASTM D 2628	Chloroprene (neoprene)
N/A	Silicone Nitrile Rubber

c. Aircraft hydraulic fluid definitely deteriorates joint seals.

d. Sealants containing coal tar or coal tar/polyvinyl chloride probably are the most resistant to jet fuel, hydraulic fluid, and lubricating oil because they have the least change in weight in the immersion tests.

3. The results of field inspections at six airports, Chicago O'Hare, Dulles, Atlanta Hartsfield, Denver Stapleton, Dallas/Fort Worth, and Los Angeles, for joint seal failure mechanisms and joint seal preference are:

a. Joint seal failures appear to be related to inadequate materials, improper installation, and improper design. The following defects were observed:

Chemical damage - by jet fuel, hydraulic oil, and other spilled chemicals

Physical damage - adhesion loss, cohesion cracks, intrusion of incompressibles, compression set

Environmental damage - hardness

In general, the joint sealant defects could not be linked directly to any one cause but could be the result of a combination of mechanisms. However, there is a strong indication of material deficiencies as evidenced by the failure rates in the specification conformance tests and the observed performance in the field.

b. The preferred joint seals at the respective airports are:

Airport	First Choice	Second Choice
Chicago O'Hare	Crafco RS-201	Sealtight Poly-Jet JFR
Dulles	Dow Corning 888*	Sealtight Poly-jet JFR*
Atlanta Hartsfield	Allied 9012 Superseal 777	Dow Corning 888
Denver Stapleton	Dow Corning 888	Crafco RS-201
Dallas/Fort Worth	Dow Corning 888	(hot-poured)
Los Angeles	Grove GS-1450	Elasto-thane 5639

*Opinion of contractor at Dulles.

4. Candidate seals selected for field testing in Phase II are:

	Material Type
Dow Corning 888	Silicone
Grove GS-1450	Polyurethane
Tex-Mastic Thermoseal	Coal Tar, Polyvinyl Chloride
WC-1250 (preformed)	Chloroprene

PRELIMINARY RECOMMENDATIONS FOR ESSENTIAL JOINT SEAL CHARACTERISTICS

Based on qualitative analyses, laboratory tests, and field observations, the essential characteristics of airport pavement joint sealants recommended for incorporation in specifications are that sealants should be:

a. Resistant to aircraft fluids - jet fuel, hydraulic fluid, and lubricating oil.

b. Capable of elongating and compressing without damage - to accommodate thermal expansion and contraction of adjacent pavement slabs of magnitudes as described in Reference 7.

c. Capable of rejecting intrusion of incompressibles.

d. Capable of withstanding temperatures from subfreezing to +500 ^{o}F without damage (reference: Federal Specification SS-S-200E).

e. Resistant to degradation by sunlight and weathering.

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TABLE 1. FINDINGS FROM SURVEY OF FAA REGIONAL ENGINEERS.

Regional Office	Findings
Alaska	No data on best performing sealants. Recommend contact airport engineers. Use mostly asphalt pavement in this region due to climate.
Northwest-Mountain	No data on best performing sealants. Recommend contact airport engineers.
Western-Pacific	No data on best performing sealants. Recommend contact airport engineers.
New England	No data on best performing sealants. Use mostly asphalt pavement in this region.
Southwest	Believes Silicone sealants are best, such as Dow Corning 888 or GE. Have had problems with installation workmanship of preformed seals.
Eastern	Believes silicone sealants are best, based on highway experiences. Heard Dow Corning 888 performs well. 80 % of airport pavement in region is asphalt, ie., overlays. PCC used on new construction only. Not very many newly constructed pavements in region.
Southern	No data on best performing sealant. Recommend contact airport engineers.

TABLE 2. AIRPORTS SELECTED FOR SITE SURVEY AND CORRESPONDING CLIMATIC ZONES.

Airport	Climatic Zone
Chicago O'Hare	Wet-freeze
Dulles	Wet-freeze-thaw
Atlanta Hartsfield	Wet-no freeze
Denver Stapleton	Dry-freeze
Dallas/Fort Worth	Dry-freeze-thaw
Los Angeles	Dry-no freeze

TABLE 3. CANDIDATE SEALANTS SELECTED FOR LABORATORY TESTING.

Sealant	Manufacturer	Material Type	Intended Federal or ASTM Specification
Anti-Hydro Urethane Bitumen Sealant JFR	Anti-Hydro Co.	coal tar, polyurethane	SS-S-200D
Crafco RS-201	Crafco, Inc.	asphalt, rubber	ASTM D-3405 SS-S-1401C
Delastic Series E-1253	D.S. Brown Co.	chloroprene	ASTM D-2628
Dow Corning 888	Dow Corning Corp.	silicone	N/A
Elasto-Thane 5639 Type H	Pacific Polymers, Inc.	polyurethane	SS-S-200D
Grove GS-1450	Grove International, Inc.	polyurethane	SS-S-200D
Koch 1614	Koch Materials Co.	coal tar, polyvinyl chloride	ASTM D-3581 SS-S-1614
Koch 3569	Koch Materials Co.	coal tar, polyvinyl chloride	ASTM D-3569
Koch 9012	Koch Materials Co.	coal tar, polyvinyl chloride	ASTM D-3569 SS-S-1614
Koch 9020	Koch Materials Co.	coal tar	SS-S-200D
Sealtight Gardox	W.R. Meadow, Inc.	coal tar	SS-S-200D
Sealtight Hi-Spec	W.R. Meadow, Inc.	asphalt	ASTM D-3405 SS-S-1401C
Sealtight Poly-Jet JFR	W.R. Meadow, Inc.	coal tar, polyvinyl chloride	ASTM D-3569 ASTM D-3581 SS-S-1614
Superseal 777	Superior Products Co., Inc.	coal tar	ASTM D-3569 SS-S-1614
Tex-mastic Hotpour-Spec	J&P Petroleum Prod., Inc.	asphalt, rubber	ASTM D-3405 SS-S-1401
Tex-mastic Thermoseal	J&P Petroleum Prod., Inc.	coal tar, polyvinyl chloride	ASTM D-3406 ASTM D-3569 SS-S-1614
Vulkem 202	Mameco International	coal tar, polyurethane	SS-S-200D
WC-1250	Watson-Bowman & Acme Corp.	chloroprene	ASTM D-2628
Jamak Solasil 100/500	Jamak Inc.	preformed silicone gasket/silicone	N/A
Ruscoe 983	W.J. Ruscoe Co.	nitrile rubber	N/A

TABLE 4. AIRPORT SITE SURVEY RESULTS.

Airport	Sealant#/ Manufacturer	Material Type	Federal or ASTM Specification	Age (years)	Defects	Remarks
O'Hare (wet-freeze)	RS-201 Crafco	Asphalt-rubber	ASTM D 3405	5-6	hardness, extrusion	
	Sealtight Poly-Jet JFR W. R. Meadows	Polyvinyl chloride	ASTM D 3581			
	Sealtight Hi-Spec W. R. Meadows	Asphalt-rubber	ASTM D 3405			
Dulles (wet-freeze-thaw)	888 Dow Corning	Silicone	N/A	3-8		All of this data was provided by a contractor. No data available from airport.
	Sealtight Poly-Jet JFR W. R. Meadows	Polyvinyl chloride	ASTM D 3405			
Atlanta (wet-no freeze)	Superseal 777 Superior Prod.	Asphalt(?)	ASTM D 3569	7-8	adhesion loss, cohesion loss, hardness, brittleness	
	9012 Allied Chemical	(?)	SS-S-1614	2-3	adhesion loss, surface bubbles, surface crystalization	
	888 Dow Corning	Silicone	N/A			Just installed, no defects observed.
	(Preformed) Watson-Bowman & Acme	(?)			compression set, oxidation, adhesion loss	
Denver (dry-freeze)	888 Dow Corning	Silicone	N/A	2-3	none	Good adhesion and bonding
	RS-201 Crafco	Asphalt-rubber	ASTM D 3405		hardness	
	Preformed E-1250 D. S. Brown	(?)	ASTM D 2628		Preformed sealants not inspected - bad weather.	For preformed seals: no sealant preference, recommend for new construction only.
	Preformed A-125 Acme Highway Prod.	(?)	ASTM D 2628			

TABLE 4. AIRPORT SITE SURVEY RESULTS (Continued).

Airport	Sealant*/ Manufacturer	Material Type	Federal or ASTM Specification	Age (years)	Defects	Remarks
	Preformed WC-1250 Watson-Bowman & Acme	(?)	ASTM D 2628			
	Superseal 777 Superior Prod.	Asphalt (?)	ASTM D 3569		shrinkage, pull outs, hard, cracks, no bond	
Dallas/Fort North (dry-freeze-thaw)	888 Dow Corning	Silicone	N/A	<1	none	Just installed.
	(Hot-poured) Manufacturer(?)					
	(Preformed) Manufacturer(?)				lack resiliency pulled out	
Los Angeles (dry-no freeze)	GS-1450 Grove Int.	Polyurethane	SS-S-200	7	adhesion loss, blistering, Skydrol damage	
	Elasto-thane 5639 Pacific Polymers	Polyurethane	SS-S-200	5-6	adhesion loss, hardness, seal loss	
	Superseal 777 Superior Prod.	Asphalt (?)	ASTM D 3569	2-3	adhesion loss, hardness, Skydrol damage, jet-fuel damage, bleeding	

* Sealants are listed in order of preference by engineers and maintenance personnel at the repective airports.

TABLE 5. JOINT SEALS PREFERRED BY VARIOUS AIRPORT PERSONNEL.

Airport	First Choice	Second Choice	Third Choice
Chicago O'Hare	Crafco RS-201	Sealtight Poly-Jet JFR	Sealtight Hi-Spec
Dulles	Dow Corning 888*	Sealtight Poly-jet JFR*	
Atlanta Hartsfield	Allied 9012 Superseal 777	Dow Corning 888	Preformed
Denver Stapleton	Dow Corning 888	Crafco RS-201	Preformed
Dallas/Fort Worth	Dow Corning 888	(hot-poured)	Preformed
Los Angeles	Grove GS-1450	Elasto-thane 5639	Superseal 777

*Opinion of contractor at Dulles.

TABLE 6. PRINCIPAL COMPONENTS OF JOINT SEAL SAMPLES IDENTIFIED BY INFRARED SPECTROSCOPY ANALYSIS.

Sealant	Intended Federal or ASTM Specification	Material Components					
		Asphalt	Coal Tar	Poly-Urethane	Polyvinyl Chloride	Rubber	Other
Anti-Hydro Urethane Bitumen Sealant JFR	SS-S-200D		X	X			
Elasto-Thane 5639 Type H	SS-S-200D			X			
Grove GS-1450	SS-S-200D			X			
Koch 9020	SS-S-200D		X				
Sealtight Gardox	SS-S-200D		X				
Vulkem 202	SS-S-200D		X	X			
Koch 1614	SS-S-1614 ASTM D 3581		X		X		
Koch 3569	ASTM D 3569		X		X		
Koch 9012	SS-S-1614 ASTM D 3569		X		X		
Sealtight Poly-Jet JFR	SS-S-1614 ASTM D 3569 ASTM D 3581		X		X		
Superseal 777	SS-S-1614 ASTM D 3569		X				
Tex-mastic thermoseal	SS-S-1614 ASTM D 3406 ASTM D 3569		X		X		
Crafco RS-201	SS-S-1401C ASTM D 3405	X				X	
Sealtight Hi-Spec	SS-S-1401C ASTM D 3405	X					
Tex-mastic Hotpour-Spec	SS-S-1401 ASTM D 3405	X				X	
Delastic Series E-1253	ASTM D 2628						chloroprene
WC-1250	ASTM D 2628						chloroprene
Dow Corning 888	N/A						silicone
Jamak Solasil 100/500	N/A						silicone
Ruscoe 983	N/A						nitrile rubber

TABLE 7. RESULTS OF TESTS ON JOINT SEALS FOR SPECIFICATION CONFORMANCE.

Sealant	Specification	Passed	Failed
Anti-Hydro Urethane Bitumen Sealant JFR	SS-S-200E		X
Elasto-Thane 5639	SS-S-200E		X
Grove GS-1450	SS-S-200E		X
Koch 9020	SS-S-200E		X
Sealtight Gardox	SS-S-200E		X
Vulkem 202	SS-S-200E	no data	
Dow Corning 888	SS-S-200E		X
Jamak Solasil 100/500	SS-S-200E		X
Ruscoe 983	SS-S-200E	no data	
Koch 1614	ASTM D 3569-85 (SS-S-1614)		X
Koch 3569	ASTM D 3569-85 (SS-S-1614)		X
Koch 9012	ASTM D 3569-85 (SS-S-1614)		X
Sealtight Polyjet JFR	ASTM D 3569-85 (SS-S-1614)		X
Superseal 777	ASTM D 3569-85 (SS-S-1614)		X
Tex-mastic Thermoseal	ASTM D 3569-85 (SS-S-1614)		X
Crafco RS-201	ASTM D 3405 SS-S-1401	X	
Sealtight Hi-Spec	ASTM D 3405 SS-S-1401		X
Tex-mastic Hotpour-Spec	ASTM D 3405 SS-S-1401	X	
Delastic Series E-1253	ASTM D 2628		X
Watson Bowman WC-1250	ASTM D 2628	X	

TABLE 8A. FEDERAL SPECIFICATION SS-S-200E CONFORMANCE TEST RESULTS.

(Sat = Satisfactory, Unsat = Unsatisfactory.)

Tests	SS-S-200E Requirements	Sealant							
		Anti-Hydro Urethane Bitumen	Dow Corning 888	Koch Materials 9020	Pacific Polymers Elasto-thane 5639	Mameco Int'l Vulkem 202	Grove GS-1450	W. J. Ruscoe 983	W. R. Meadows Gardox
Accelerated Aging at 120 $^{\circ}$F, 21 Days	Sat[1]	No data	No data	No data	Sat	No data	No data	No data	Sat
Self Leveling: Level Plane	Sat[2]	Sat	No data	Sat	Sat	No data	Sat	No data	Sat
1.5% Incline	Sat[2]	Sat	No data	Sat	Sat	No data	Sat	No data	Sat
Change in Weight by Fuel Immersion	<2.0% of initial weight	1.66	-2.80	0.72	3.65	No data	2.51	No data	0.07
Change in Volume at 158 $^{\circ}$F, 168 hr	<5.0% of initial volume	2.39	-0.84	1.44	0.21	No data	0.65	No data	1.40
Resilience: Unaged -	Recovery >75%	97	95	95	98	No data	100	No data	97
	0.05-0.20 cm initial indentation	0.06	0.03	0.08	0.02	No data	0.01	No data	0.06
Aged -	Recovery >75%	100	94	93	100	No data	100	No data	100
	0.05-0.20 cm initial indentation	0.03	0.04	0.07	0.04	No data	0.01	No data	0.0
Resistance to Artificial Weathering at 140 $^{\circ}$F, 160 hr	Sat[3]	Sat	Sat	Sat	Sat	No data	Sat	No data	Sat
	Sat[4]	Sat	Sat	Sat	Sat	No data	Sat	No data	Sat
	<5.0% of initial weight volume change	1.38	-0.32	0.90	-1.05	No data	0.17	No data	0.57
Bond, at -20 $^{\circ}$F: Non-Immersed	Sat[5]	Unsat	No data	Sat	Sat	No data	Sat	No data	Sat
Fuel-Immersed	Sat[5]	Sat	No data	Sat	Sat	No data	Sat	No data	Sat
Water-Immersed	Sat[5]	Sat	No data	Sat	Sat	No data	Sat	No data	Sat
Flow	Sat[6]	Sat	No data	Sat	Sat	No data	Sat	No data	Sat

Notes:

1. No settling, separation, or hardening that will not return to a homogeneous liquid by simple stirring; no skinning greater than 1/16-inch thick.
2. No flow to a variation of the surface greater than 1/8 inch.
3. No breakdown of cure or reversion of the sealant.
4. No blistering or deformation greater than "blister size No. 2" and classed as "medium dense" in accordance with ASTM D 714.
5. None of the specimens shall develop any surface checking, cracks, separation, or other opening in the sealant. No hardness or loss of rubber-like characteristics in the sealant.
6. No cracking or dimensional change.

TABLE 8B. RESULTS OF ADDITIONAL IMMERSION TESTS USING FEDERAL SPECIFICATION SS-S-200E TEST PROCEDURES.

(Sat = Satisfactory, Unsat = Unsatisfactory)

Tests	SS-S-200E Requirements	Sealant							
		Anti-Hydro Urethane Bitumen	Dow Corning 888	Koch Materials 9020	Pacific Polymers Elasto-thane 5639	Mameco Int'l Vulkem 202	Grove GS-1450	W. J. Ruscoe 983	W. R. Meadows Gardox
Change in Weight:									
1. Hydraulic Fluid (MIL SPEC H-83282B)	<2.0% of initial weight	0.58	-0.48	No data	0.97	No data	0.55	No data	0.48
2. Lubricating Oil (MIL SPEC L-23699C)	<2.0% of initial weight	0.09	0.08	No data	1.62	No data	1.14	No data	-0.17
Change in Volume:									
1. Reference Fuel B (ASTM D 471)	<5.0% of initial volume	4.78	1.01	1.97	-2.69	No data	-0.82	No data	3.14
2. Hydraulic Fluid (MIL SPEC H-83282B)	<5.0% of initial volume	2.65	0.91	1.36	-1.10	No data	0.02	No data	0.94
3. Lubricating Oil (MIL SPEC L-23699C)	<5.0% of initial volume	1.99	-9.18	1.44	-1.70	No data	-1.04	No data	1.21
Weatherometer, Volume Change:									
1. Reference Fuel B (ASTM D 471)	<5.0% of initial volume	2.21	0.46	2.01	-3.67	No data	-2.03	No data	0.55
2. Hydraulic Fluid (MIL SPEC H-83282B)	<5.0% of initial volume	2.06	0.50	0.36	-1.16	No data	-0.14	No data	1.32
3. Lubricating Oil (MIL SPEC L-23699C)	<5.0% of initial volume	1.37	-1.25	1.53	-1.91	No data	-2.68	No data	0.50
Bond, at -20°F:									
1. Hydraulic Fluid (MIL SPEC H-83232B)	Sat[1]	Sat	No data	Sat	Sat	No data	Sat	No data	Unsat
2. Lubricating Oil (MIL SPEC L-23699C)	Sat[1]	Sat	No data	Sat	Sat	No data	Sat	No data	Unsat

Note:
1. None of the specimens shall develop any surface checking, cracks, separation, or other openings in the sealant. No hardness or loss of rubber-like characteristics in the sealant.

TABLE 9A. ASTM D 3569-85 CONFORMANCE TEST RESULTS.

(Sat = Satisfactory, Unsat = Unsatisfactory)

Tests	D 3569-85 Requirements	Sealant					
		J&P Petroleum Thermoseal	Koch Materials 9012	Koch Materials NEA 1614*	Koch Materials NEA 3569*	Superior Products Superseal 777	W.R. Meadows Poly-Jet JFR
Penetration, at 77°F: Non-Immersed	<1.30 cm	0.69	0.78	-	-	1.94	0.69
Fuel-Immersed	Shall not exceed non-immersed	0.53	0.73	-	-	1.96	0.75
Flow at 72 hr, 158°F	<0.3 cm	0.0	0.0	-	-	0.0	0.0
Resilience: Unaged at 77°F	Minimum 60% recovery	74	60	-	-	56	74
Aged at 24 hr, 158°F	Minimum 60% recovery	73	54	-	-	14	57
Artificial Weathering	Sat[1]	Sat	Sat	-	-	Sat	Sat
Tensile Adhesion	Minimum 500% elongation	424	668	-	-	614	374
Flexibility	Sat[2]	Sat	Sat	-	-	Sat	Sat
Solubility (change in weight)	Maximum ±2% change in weight[3]	0.08	0.11	-	-	0.50	0.18
Bond, at 0°F: Non-Immersed	Sat[4]	Sat	Sat	-	-	Sat	Sat
Water-Immersed	Sat[4]	Unsat	Sat	-	-	Sat	Sat
Fuel-Immersed	Sat[4]	Sat	Sat	-	-	Sat	Unsat

*The material did not cure after 72 hours. The material was so thin that it did not stay in most of the molds.

Notes:
1. Shall have no physical change.
2. Shall have no indication of surface crazing or cracking.
3. Shall also have no cracking, swelling, or softening of sample to mastic-like consistency.
4. Shall show no cracking, separation, or other opening in the sealing compound or between the sealing compound and the concrete block.

TABLE 9B. RESULTS OF ADDITIONAL IMMERSION TESTS USING ASTM D 3569-85 TEST PROCEDURES.

(Sat = Satisfactory, Unsat = Unsatisfactory)

Tests	D 3569-85 Requirements	Sealant					
		J&P Petroleum Thermoseal	Koch Materials 9012	Koch Materials MEA 1614*	Koch Materials MEA 3569*	Superior Products Superseal 777	W.R. Meadows Poly-Jet JFR
Solubility (change in weight):							
1. Hydraulic Fluid (MIL SPEC H-83282B)	Maximum ±2% change in weight	0.09	0.17	-	-	0.3	0.10
2. Lubricating Oil (MIL SPEC L-23699C)	Maximum ±2% change in weight	0.10	0.54	-	-	0.6	0.36
Bond, at 0°F:							
1. Hydraulic Fluid (MIL SPEC H-83282B)	Sat[1]	Sat	Sat	-	-	Sat	Sat
2. Lubricating Oil (MIL SPEC L-23699C)	Sat[1]	Sat	Sat	-	-	Sat	Sat

*The material did not cure after 72 hours. The material was so thin that it did not stay in most of the molds.

Notes:

1. Shall show no cracking, separation, or other opening in the sealing compound or between the sealing compound and the concrete block.

TABLE 10. ASTM D 3405 CONFORMANCE TEST RESULTS.

(Sat = Satisfactory, Unsat = Unsatisfactory)

Tests	D 3405 Requirements	Sealant		
		Crafco RS-201	J&P Petroleum Hotpour-Spec	W.R. Meadows Hi-Spec
Penetration at 77°F	<0.90 cm	0.76	0.87	0.70
Flow	<0.3 cm	0.0	0.0	0.0
Resilience at 77°F	Minimum 60% recovery	67	62	77
Bond, at -20°F Non-Immersed	Sat[1]	Sat	Sat	Unsa-
Asphalt Compatibility	Sat[2]	Sat	Sat	Sat

Notes:

1. Shall show no cracking, separation, or other opening in the sealing compound or between the sealing compound and the concrete block.
2. No adhesion failure, formation of oily exudate at interface of sealant and asphalt concrete, or softening, or other deleterious effects.

TABLE 11. ASTM D 2628 CONFORMANCE TEST RESULTS.

Tests	D 2628 Requirements	Sealant	
		D.S. Brown E-1253	Watson-Bowman & Acme WC-1250
Tensile Strength	Minimum 2,000 psi	2680	2179
Elongation at Break	Minimum 250%	370	250
Hardness, Type A Durometer	55+/-5 points	61	58
Oven Aging, at 70 Hr, 212°F:			
1. Tensile Strength Loss	Maximum 20%	3.1	5.0
2. Elongation Loss	Maximum 20%	2.7	4.0
3. Hardness Change	0 to +10 points	3.8	2.0
Oil Swell, ASTM Oil 3, at 70 Hr, 212°F, Weight Change	Maximum 45%	43?	32
Ozone Resistance, 20% Strain, 300 pphm in Air, 70 Hr, 104°F	No cracks	No cracks	No cracks
Low Temperature Stiffening, at 7 Days, 14°F, Hardness Change, Type A Durometer	0 to +15 points	7.4	5.0
Low Temperature Recovery, at 72 Hr, 14°F, 50% Deflection	Minimum 88%	98	98
Low Temperature Recovery, at 22 Hr, -20°F, 50% Deflection	Minimum 83%	92	95
High Temperature Recovery, at 70 Hr, 212°F, 50% Deflection	Minimum 85%	93	90
Compression/Deflection at 80% Nominal Width	Minimum 3.5 lbf/in	6.9	7.1

TABLE 12. RESULTS OF IMMERSION TESTS IN JET FUEL, HYDRAULIC FLUID, AND LUBRICATING OIL.

Sealant	Material Composition	Immersion Test Results % Change in Weight		
		Reference Fuel B (ASTM D 471)	Hydraulic Fluid (MIL SPEC H-83282B)	Lubricating Oil (MIL SPEC L-23699C)
Federal Specification SS-S-200E Sealants				
Anti-Hydro Urethane Bitumen	coal tar, polyurethane	1.66	0.58	0.69
Dow Corning 888	silicone	-2.80	-0.48	0.08
Koch 9020	coal tar	0.72	no data	no data
Pacific Poly. 5639	polyurethane	3.65	0.97	1.62
Grove GS-1450	polyurethane	2.51	0.55	1.14
W.R. Meadows Gardox	coal tar	0.07	0.48	-0.17
ASTM D 3569-85 (or Federal Specification SS-S-1614) Sealants				
J&P Petroleum Thermoseal	coal tar, PVC	0.08	0.09	0.10
Koch 9012	coal tar, PVC	0.11	0.17	0.54
Superior Products Superseal 777	coal tar	0.5	0.3	0.6
W.R. Meadows Poly-jet JFR	coal tar, PVC	0.18	0.1	0.36

TABLE 13. TYPES OF MATERIALS USED FOR SEALANTS AND THEIR COMPATIBILITY TO AVIATION FLUIDS.

Sealant Material Compositions	Comments
Asphalt, bitumen, coal tar or pitch	Generally soluble in JP-4, JP-5 and other liquids containing aromatic hydrocarbons.
Polyvinylchloride (PVC)	Very soluble in most ketones (including MEK and acetone), esters and alcohols, as well as chlorinated hydrocarbons.
Natural Rubber	Will swell in the presence of many hydrocarbons, even if vulcanized.
Chloroprene (Neoprene), butyl rubber and other synthetic rubbers	More chemically resistant than natural rubber, but may swell or dissolve in MEK and Skydrol[R] aviation hydraulic fluid.
Polyurethanes (PU)	Completely cross-linked PU should be very stable to most solvents. However, combinations of coal tar or asphalt with PU are attacked by many aircraft fluids.
Silicones	The phenyl and methyl silicones are very chemically resistant (at room temperature) to most solvents, oils, greases, and fuels.
Polysulfides	Polysulfides, such as Thiokol A[R] and Thiokol FA[R], were not listed in any of the sealant formulations. However, these "thiorubbers" are very resistant to organic solvents and dilute mineral acids (unstable to alkali, such as that used in cleaning solutions meeting MIL-C-87936).

TABLE 14. QUALITATIVE ASSESSMENT OF JOINT SEALANT-AIRCRAFT FLUID COMPATIBILITY.

Sealant Name	Turbine Fuel MIL-T-5624	Lubricating Oil MIL-L-7808	Lubricating Oil MIL-L-23699	Hydraulic Fluid MIL-H-83282	Hydraulic Fluid Skydrol[R]	Cleaning Compounds MIL-C-87936	Methyl Ethyl Ketone	Hydraulic Fluid MIL-H-5606
Federal Specification SS-S-200								
Anti-Hydro Urethane Bitumen Sealant JFR	F	F	F	F	U	U	U	F
Koch 9020	U	F	F	F	U	U	U	F
Vulkem 202	F	F	F	F	U	F	F	F
Elasto-thane 5639	G	E	E	E	F	G	G	E
Superseal 777	U	F	F	F	U	U	U	F
Grove GS-1450	G	E	E	E	F	G	G	E
Federal Specification SS-S-1401								
Crafco RS-201	F	F	F	F	U	F	U	F
Sealtight Hi-Spec	U	F	F	F	U	U	U	F
Federal Specification SS-S-1614								
Tex-Mastic Hotpour-Spec	F	F	F	F	U	U	U	F
Tex-Mastic Thermoseal	U	U	U	U	U	U	U	U
Koch 9012	F	F	F	F	U	U	U	F
Koch 1614	F	F	F	F	U	U	U	F
Superseal 777	U	F	F	F	U	U	U	F
Sealtight Poly-Jet JFR	U	F	F	F	U	U	U	F

TABLE 14. QUALITATIVE ASSESSMENT OF JOINT SEALANT-AIRCRAFT FLUID COMPATIBILITY (Continued).

Sealant Name	Turbine Fuel MIL-T-5624	Lubricating Oil MIL-L-7808	Lubricating Oil MIL-L-23699	Hydraulic Fluid MIL-H-83282	Hydraulic Fluid Skydrol^R	Cleaning Compounds MIL-C-87936	Methyl Ethyl Ketone	Hydraulic Fluid MIL-H-5606
ASTM D2628 (Neoprene preformed compression seals)								
Delastic Series E-1253	G	E	E	G	F	G	F	G
MC-1250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silicone								
Dow Corning 888	E	E	E	E	G	E	E	E

Notes: E = Excellent, G = Good, F = Fair, U = Unsatisfactory, N/A = No information available on sealant composition. For estimates of durability for long-term exposure to specified chemical or heat (no lab tests were conducted at NCEL).

TABLE 15a. RELATIVE PERFORMANCE RATINGS OF FEDERAL SPECIFICATION SS-S-200E TESTED JOINT SEALS.

Tests	Anti-Hydro Urethane Bitumen	Pacific Polymers Elasto-thane 5639	Grove GS-1450	W.R. Meadows Gardox
Change in Weight by Fuel Immersion	2	4	3	1
Change in Volume at 158°F, 168 hrs	4	1	2	3
Resilience:				
Unaged	3	2	1	3
Aged	1	1	1	1
Resistance to Artificial Weathering ay 140°F, 160 hrs (volume change)	4	3	1	2
Change in Weight (after immersion):				
Hydraulic Fluid	3	4	2	1
Lubricating Oil	1	4	3	2
Change in Volume (after immersion at 158°F, 168 hrs):				
Reference Fuel B	4	2	1	3
Hydraulic Fluid	4	3	1	2
Lubricating Oil	4	3	1	2
Change in Volume (weatherometer):				
Reference Fuel B	3	4	2	1
Hydraulic Fluid	4	2	1	3
Lubricating Oil Immersion	2	3	4	1
Total Performance Ratings	39	36	23	25

Notes:

(1) A PERFORMANCE RATING value of 1 denotes the best performing joint seal for that test. Performance Ratings are based on a comparison of specification conformance test results of seals tested.

(2) The TOTAL PERFORMANCE RATING is the sum of performance ratings for each joint seal. The lowest total performance rating value (bold face) denotes the best performing joint seal of that particular specification.

TABLE 15b. RELATIVE PERFORMANCE RATINGS OF ASTM D 3569-85 TESTED JOINT SEALS.

Tests	J&P Petroleum Thermoseal	Koch Materials 9012	Superior Products Superseal 777	W.R. Meadows Poly-Jet JFR
Penetration at 77°F:				
Nonimmersed	1	2	3	1
Fuel Immersed	1	2	4	3
Resilience:				
Unaged at 72°F	1	2	3	1
Aged at 24 hr, 158°F	1	3	4	2
Tensile Adhesion	3	1	2	4
Solubility, Change in Weight	1	2	4	3
Solubility, Change in Weight:				
Hydraulic Fluid	1	3	4	2
Lubricating Oil	1	3	4	2
Total Performance Ratings	10	18	28	18

Notes:

(1) A PERFORMANCE RATING value of 1 denotes the best performing joint seal for that test. Performance Ratings are based on a comparison of specification conformance test results of seals tested.

(2) The TOTAL PERFORMANCE RATING is the sum of performance ratings for each joint seal. The lowest total performance rating value (bold face) denotes the best performing joint seal of that particular specification.

TABLE 15c. RELATIVE PERFORMANCE RATINGS OF ASTM D 2628 (PREFORMED COMPRESSION SEALS) TESTED JOINT SEALS.

Tests	D.S. Brown E-1253	Watson-Bowman & Acme WC-1250
Tensile Strength	1	2
Elongation at Break	1	2
Hardness	2	1
Oven Aging at 70 hrs, 212°F:		
Tensile Strength Loss	1	2
Elongation Loss	1	2
Hardness Change	2	1
Oil Swell (weight change at 70 hrs, 212°F)	2	1
Low Temperature Stiffening Hardness Change at 7 days, 14°F	2	1
Low Temperature Recovery:		
At 72 hrs, 14°F	1	1
At 22 hrs, -20°F	2	1
High Temperature Recovery at 70 hrs, 212°F	1	2
Compression-Deflection at 80% of Nominal Width	2	1
Total Performance Ratings	18	17

Notes:

(1) A PERFORMANCE RATING value of 1 denotes the best performing joint seal for that test. Performance Ratings are based on a comparison of specification conformance test results of seals tested.

(2) The TOTAL PERFORMANCE RATING is the sum of performance ratings for each joint seal. The lowest total performance rating value (bold face) denotes the best performing joint seal of that particular specification.

TABLE 16. JOINT SEALS SELECTED FOR PHASE II FIELD TESTS.

Sealant Name/Manufacturer	Specification	Material Type
Dow Corning 888 Dow Corining Corp. Midland, MI 48686-0994	FAA (Draft)	Silicone
Grove GS-1450 Grove International, Inc. 135 S. Thurston Ave. Los Angeles, CA 90049	FED SPEC SS-S-200E	Polyurethane
Tex-mastic Thermoseal J&P Petroleum Products, Inc. P.O. Box 4206 Dallas, TX 75208	ASTM D 3569	Coal Tar, Polyvinyl Chloride
WC-1250 Watson-Bowman & Acme Corp. 95 Pineview Dr. Amherst, NY 14120	ASTM D 2628	Chloroprene

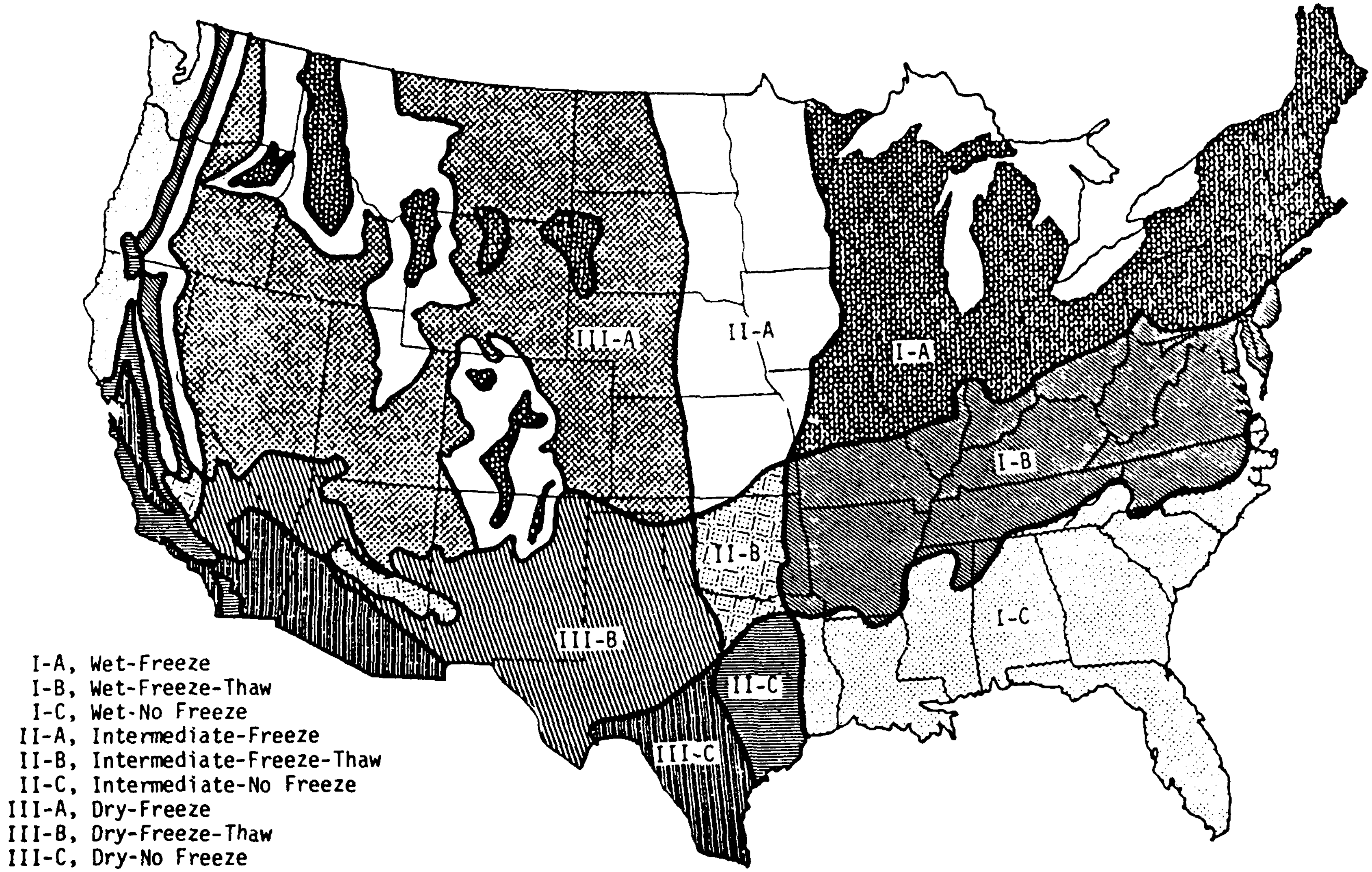

FIGURE 1. U.S. CLIMATIC ZONES (FROM REF 9).

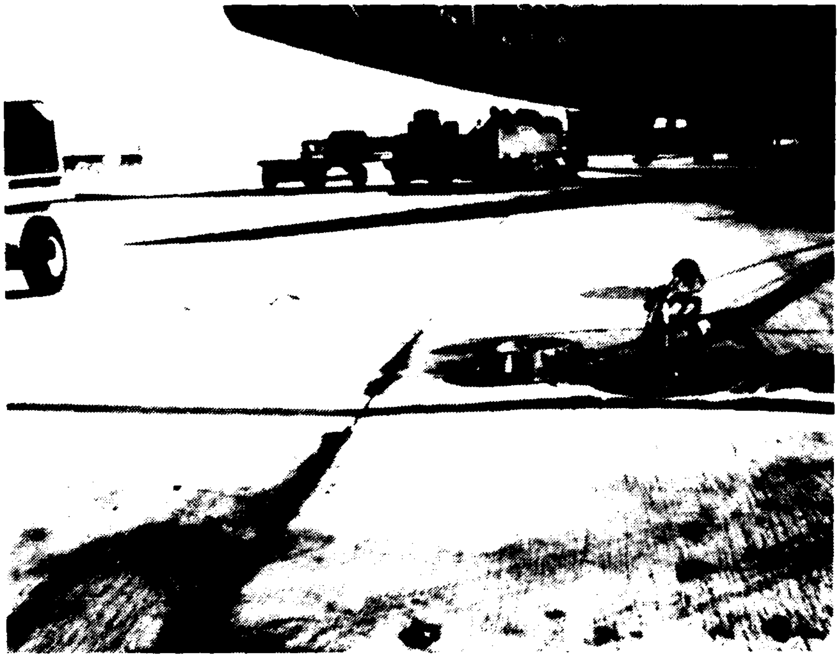

FIGURE 2. PARKING APRON AND AIRCRAFT REFUELING AT LOS ANGELES INTERNATIONAL AIRPORT.

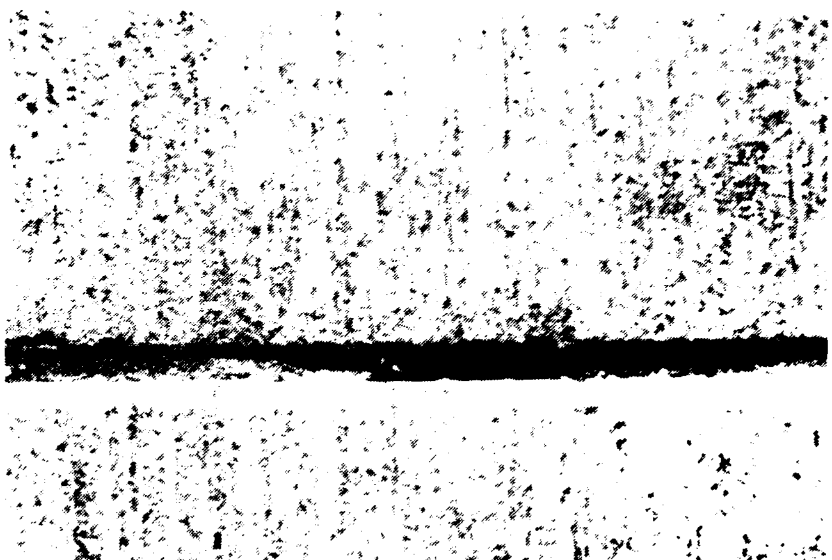

FIGURE 3. JET-FUEL DAMAGE OF JOINT SEAL ON PARKING APRON AT LOS ANGELES INTERNATIONAL AIRPORT.

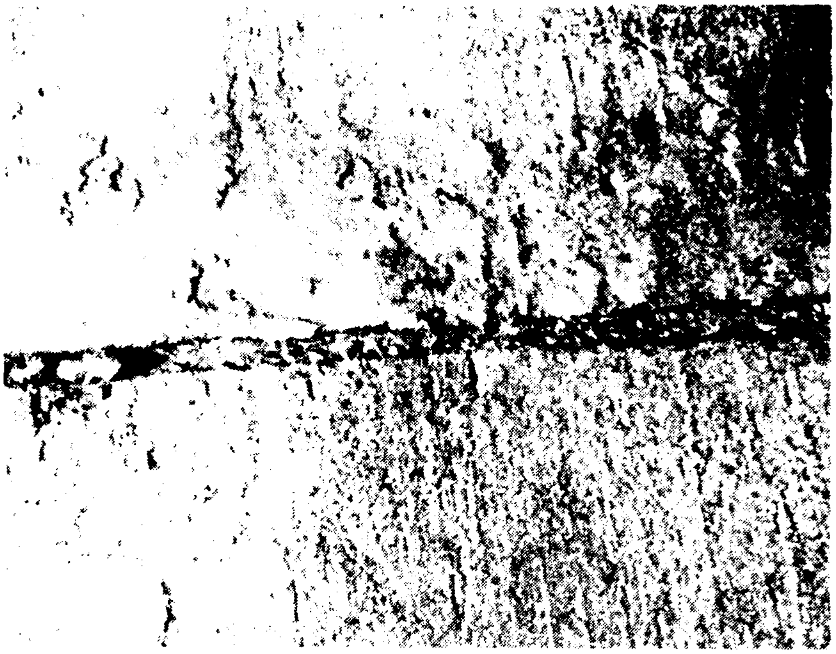

FIGURE 4. HYDRAULIC FLUID DAMAGE OF JOINT SEAL ON PARKING APRON AT LOS ANGELES INTERNATIONAL AIRPORT.

FIGURE 5. ADHESION LOSS OF JOINT SEAL AT ATLANTA HARTSFIELD INTERNATIONAL AIRPORT.

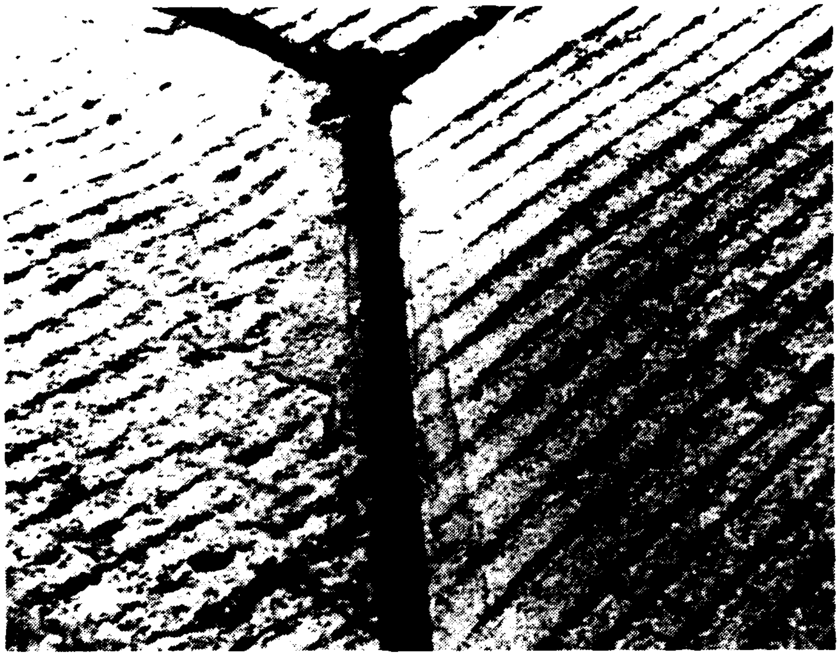

FIGURE 6. COHESION LOSS OF JOINT SEAL AT ATLANTA HARTSFIELD INTERNATIONAL AIRPORT.

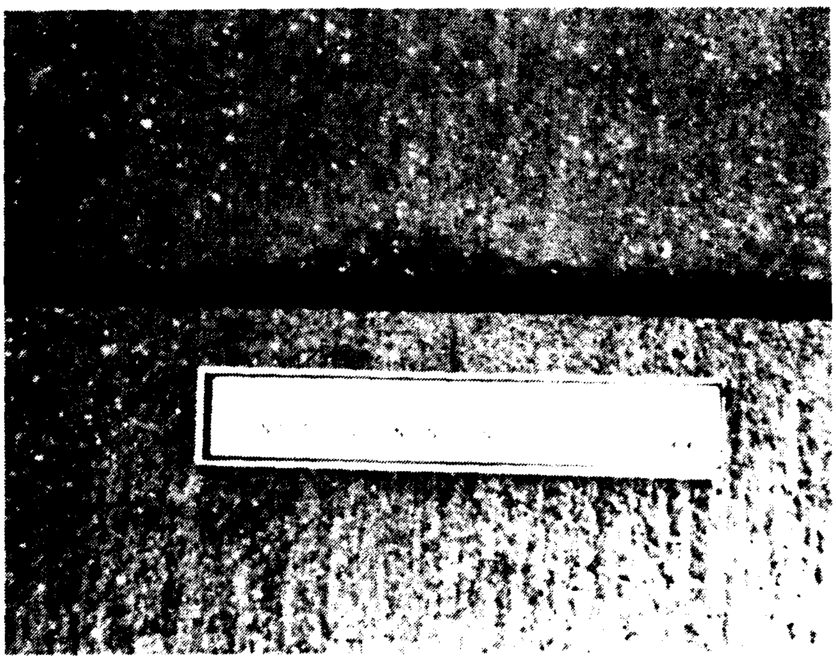

FIGURE 7. HARDNESS OF JOINT SEAL ON RUNWAY AT DENVER STAPLETON INTERNATIONAL AIRPORT.

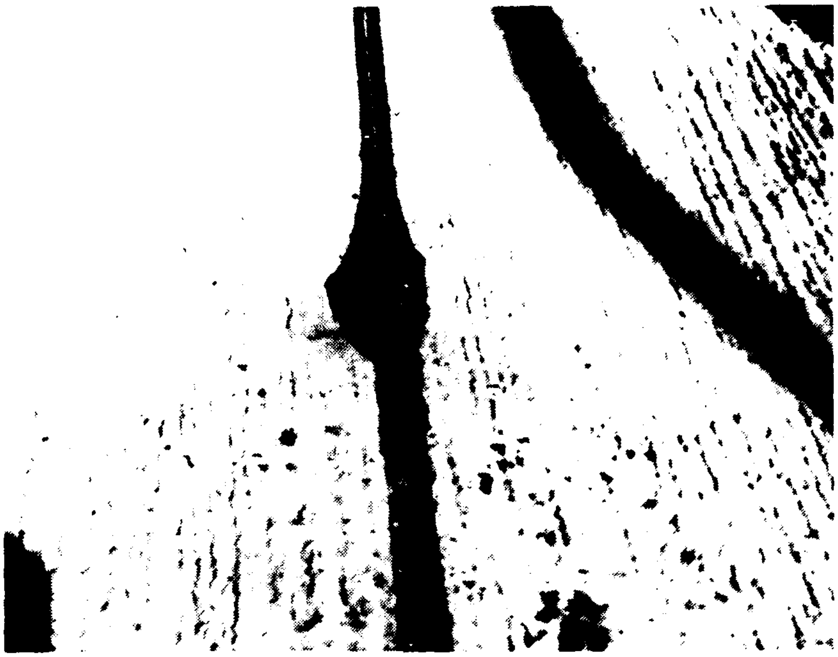

FIGURE 8. COMPRESSION SET OF PREFORMED COMPRESSION SEAL AT ATLANTA HARTSFIELD INTERNATIONAL AIRPORT.

Appendix A

JOINT SEAL GLOSSARY

JOINT SEAL GLOSSARY
(after References 7 and 8)

Accelerated aging: Creating conditions in a short time that are usually obtained in normal aging conditions. Conditions normally employed are heat, light, or oxygen.

Adhesion: The interfacial force caused by valence or attraction forces between two material surfaces.

Adhesion failure: The loss of adhesion between the joint sealant and concrete joint wall interface.

Aging: The progressive change in physical and chemical properties of materials. Primary cause of aging is oxidation.

Asphalt: Solid or semisolid mineral pitch or bitumen which occurs naturally.

Bitumen: Formally known for mineral pitch or asphalt. Currently for many flammable mineral substances which consist of hydrocarbons.

Bleeding: The migration of various materials, such as plasticizers or waxes, within the sealant to the surface.

Blistering: The formation of pockets of air or gas within the sealant which deforms the surface.

Blow-up, pavement: A pavement distress in which the intrusion of incompressibles or improperly designed joints prevents the expansion of the pavement due to temperature and moisture.

Bond breaker: A material placed at the bottom of a joint to prevent undesirable adhesion between the sealant and the bottom of the joint.

Brittleness: The tendency of a seal to crack or crumble when subjected to deformation.

Chloroprene: A substance used in the manufacture of neoprene, a synthetic rubber.

Cohesion: The form of attraction in which particles of a body are held together by internal forces. The internal strength of a sealant.

Cohesive failure: The tearing of the sealant when the internal strength is exceeded during joint expansion or shrinking of the sealant.

Compression seal: A type of joint seal with compartments or cells which provide a seal while compressed between the joint faces.

Compression set: A defect in which a compression seal is unable to regain its original shape after compression is released.

Cracking: The development of surface fissures on a sealant.

Cure: The setting or hardening of a material by chemical reaction or heating.

Deterioration: The undesirable change in properties of a seal material caused by weathering, exposure to chemicals, or aging.

Elasticity: The property of a seal material which returns to its original shape after deformantion.

Elastomer: A material which rapidly returns to its original dimensions after the release of a large deformation and stress.

Elongation: An increase in length expressed numerically by a fraction or percentage of initial length.

Fatigue failure: Failure of the sealant material under cyclic deformations.

Field-molded sealant: A liquid or semisolid seal material molded into the desired shape in the joint.

Hardness: The property or defect of a seal material which resists indentation.

Ice heave: A type of pavement distress in which a portion of the pavement raises as a result of ice crystals forming in a frost-susceptible subgrade or base course; also called frost heave.

Immersion: The placing of a seal material completely covered with a fluid, such as jet fuel.

Incompressibles: Materials that resist compression (i.e., small rocks, dirt, dust, debris) which can be trapped in an unsealed or defective joint thereby inhibiting the slab(s) from expanding.

Joint, construction: A type of joint, either transverse or longitudinal, which is used during construction. A transverse construction joint is created when construction stops. A longitudinal construction joint may be used in lane-at-a-time construction.

Joint, contraction: A type of joint which is used to control cracking induced by warping stresses in the pavement caused by temperature and moisture changes. Usually these joints are transverse at designated intervals. Also called weakened plane or dummy joint.

Joint, expansion: A type of joint, either transverse or longitudinal, which is provided to relieve excessive stresses in the pavement caused by the expansion of the pavement.

Joint, sawed: A transverse or longitudinal construction joint or a transverse expansion joint made by cutting the concrete with a concrete saw.

Low temperature recovery: The ability of a seal material to recover its original shape at a low temperature when a deforming load is removed.

Oxidation: The degradation of a polymeric material caused by natural aging, severe working in air, or accelerated aging in high concentrations of oxygen or ozone.

Penetrometer: An instrument used to determine the hardness or consistency of plastic or elastic solids by the penetration of a standard weighted needle on the surface of the sample under standard conditions of time, temperature, and load.

Pitch: A black or dark heavy liquid or solid substance left as a residue after distilling tar, oil, and similar materials.

Polymer: A compound formed by the reaction of simple molecules having functional groups which permit their combination to proceed to high molecular weights under suitable conditions.

Preformed sealant: A type of sealant functionally preshaped during manufacture and usually made of chloroprene. It is installed by compressing and forcing it in a joint whose sides have been coated with an adhesive.

Primer: A material applied to joint walls before the installation of field-molded sealants to improve adhesion of the sealant to the concrete.

Resilience: The amount of energy recoverable when the force producing the deformation is removed.

Sandblast: A cleaning method to prepare a joint for sealing. It is used to remove all foreign matter from the walls and upper edges of the joint, such as concrete curing membrane compound, laitance, and old sealant.

Shape factor: The depth to width ratio of the sealant material in the joint; a major factor in the design of the joint.

Swelling: The property of a material in which any increase in volume of the material is caused by the absorption of a liquid.

Tensile strength: The capacity of a material to resist a force tending to stretch it or the force required to stretch to rupture; also called breaking load, breaking stress, or ultimate tensile stress.

Ultraviolet light: A form of light energy in the spectrum of sunlight beyond violet with wavelengths less than 3,900 Angstrom units.

Polyurethane: A synthetic polymer that may be either thermoplastic or thermosetting and can range in consistancy from a soft, rubber-like material to a hard, brittle-like material.

Appendix B

AIRPORT SITE SURVEY QUESTIONS

AIRPORT PAVEMENT JOINT SEALANT SURVEY

A. GENERAL INFORMATION:

Airport:______________________________ Date:__________

Contact:__________________________ Phone:____________

1. Is a MAINTENANCE/MANAGEMENT SYSTEM used? If yes, explain and use this system to obtain required data. Are there RECORDS?

2. Are there any TEST DATA or EVALUATIONS of sealants available? If yes, obtain reports, data, results, etc.

B. SEALANT INFORMATION:

1. Sealants used:
   a. sealant MANUFACTURER (name, address, phone, contact)
   b. BRAND NAME
   c. SPEC. type (i.e., SS-S-200, ASTM D1854, etc.)
   d. TYPE (i.e., hot-poured, two-component cold-poured)
   e. WARRANTY
   f. PROJECTED LIFE

2. General LOCATION of sealant (i.e., gate 12, taxiway 3, parking apron).

3. Type of AIRCRAFT USAGE and VOLUME OF TRAFFIC.

4. SIZE of slab (i.e., width, length, and thickness).

5. DATE of installation or approximate AGE of sealant.

6. Who installed the sealant? (i.e., in-house, by contract).

7. How was the joint PREPARED and CLEANED? (i.e., sand-blasted).

8. What kind of BACKER ROD is used?

C. SEALANT CONDITION:

1. What is the general CONDITION of the joints?

2. What types of sealant FAILURES are there?

3. What are the possible CAUSES of these failures?

D. What is the BEST PERFORMING JOINT SEALANT? (contact's opinion and experiences of sealants).

Appendix C

SELECTED JOINT SEALANTS FOR LABORATORY TESTS

TWENTY JOINT SEALANTS SELECTED FOR LABORATORY TESTS

SEALANT/MANUFACTURER	SPECIFICATION
1. Anti-Hydro Urethane Bitumen Sealant JFR Anti-Hydro Co. 265 Badger Ave. Newark, NJ 07108	Fed Spec SS-S-200D
2. Crafco RS-201 Crafco, Inc. 6975 W. Crafco Way Chandler, AZ 85226	ASTM D-3405 Fed Spec SS-S-1401C
3. Delastic Series E-1253 D.S. Brown Co. P.O. Box 158 North Baltimore, OH 45872	ASTM D-2628
4. Dow Corning 888 Dow Corning Corp. Midland, MI 48686-0994	N/A
5. Elasto-thane 5639 Type H Pacific Polymers, Inc. 12271 Monarch St. Garden Grove, CA 92641	Fed Spec SS-S-200D
6. Grove GS-1450 Grove International, Inc. 135 S. Thurston Ave. Los Angeles, CA 90049	Fed Spec SS-S-200D
7. Jamak Solasil 100/500 Jamak Inc. 1401 N. Bowie Dr. Weatherford, TX 76086	N/A
8. Koch 1614 Koch Materials Co. 4334 Northwest Expressway, Suite 281 Oklahoma City, OK 73116	ASTM D-3581 Fed Spec SS-S-1614
9. Koch 3569 Koch Materials Co. 4334 Northwest Expressway, Suite 281 Oklahoma City, OK 73116	ASTM D-3569

SEALANT/MANUFACTURER	SPECIFICATION
10. Koch 9012 Koch Materials Co. 4334 Northwest Expressway, Suite 281 Oklahoma City, OK 73116	ASTM D-3569 Fed Spec SS-S-1614
11. Koch 9020 Koch Materials Co. 4334 Northwest Expressway, Suite 281 Oklahoma City, OK 73116	Fed Spec SS-S-200D
12. Ruscoe 983 W.J. Ruscoe Co. 485 Kenmore Blvd. Akron, OH 44301	N/A
13. Sealtight Gardox W.R. Meadow of Arizona, Inc. 1600 S. Sarival Rd. Goodyear, AZ 85338	Fed Spec SS-S-200D
14. Sealtight Hi-Spec W.R. Meadows of Arizona, Inc. 1600 S. Sarival Rd. Goodyear, AZ 85338	ASTM D-3405 Fed Spec SS-S-1401C
15. Sealtight Poly-Jet JFR W.R. Meadows of Arizona, Inc. 1600 S. Sarival Rd. Goodyear, AZ 85338	ASTM D-3569 ASTM D-3581 Fed Spec SS-S-1614
16. Superseal 777 Superior Products Co., Inc. 445 Coney Island Drive South Sparks, NV 89431	ASTM D-3569 Fed Spec SS-S-1614
17. Tex-mastic Hotpour-Spec J & P Petroleum Products, Inc. P.O. Box 4206 Dallas, TX 75208	ASTM D-3405 Fed Spec SS-S-1401
18. Tex-mastic Thermoseal J & P Petroleum Products, Inc. P.O. Box 4206 Dallas, TX 75208	ASTM D-3406 ASTM D-3569 Fed Spec 1614
19. Vulkem 202 Mameco International 4475 E. 175th St. Cleveland, OH 44128-3599	Fed Spec SS-S-200D

SEALANT/MANUFACTURER	SPECIFICATION
20. WC-1250 Watson-Bowman & Acme Corp. 95 Pineview Dr. Amherst, NY 14120	ASTM D-2628